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ATMOSPHERIC/IONOSPHERIC/ MAGNETOSPHERIC RESEARCH USING THE CHATANIKA RADAR

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31 January 1980

Final Report for Period 1 November 1976—31 October 1979

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The Chatanika incoherent scatter radar (located near Fairbanks, Alaska) has been operated by SRI International for the Defense Nuclear Agency and has been used to investigate atmospheric/ionospheric/magnetospheric phenomena of interest to the DNA. This report summarizes the accomplishments of the past three years.

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PREFACE

The encouragement and support of Mr. Dow Evelyn over the course of this contract is gratefully acknowledged. The success of the project was primarily due to the hard work of the following SRI personnel (listed alphabetically): C. M. Code, O. de la Beaujardiere, C. H. Dawson, J. L. Dye, V. J. Elliott, C. D. Feken, J. D. Kelly, R. L. Leadabrand, C. A. Leger, M. E. Lemmons, J. A. Mainini, M. A. McCready, D. McNiel, J. Petriceks, B. J. Phillips, R. I. Presnell, C. L. Rino, G. E. Tallmadge, J. F. Vickrey, R. R. Vondrak, N. D. Wallace, B. R. White, and V. B. Wickwar.

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I INTRODUCTION

Since 1971 the Chatanika Incoherent Scatter Radar Facility has been operated by SRI International for the Defense Nuclear Agency (DNA). During that time, a number of investigations relevant to the needs of the DNA have been carried out. Because many high-latitude natural phenomena produce effects similar to those occurring in high-altitude nuclear detonations, ionospheric experiments conducted at Chatanika provide unique opportunities to broaden the data base on nuclear weapons effects.

Models of the high-latitude ionosphere are relevant to the needs of DNA because many high-latitude natural phenomena produce effects similar to those occurring in the vicinity of high-altitude nuclear detonations. The physics and chemistry derived from research on the naturally disturbed upper atmosphere can be applied to nuclear upper atmospheric phenomenology through predictive computer codes. Nuclear effects on radar and communications systems, furthermore, can be derived from experiments performed on the disturbed auroral ionosphere.

Many phenomenological and systems effects can be investigated with the Chatanika incoherent-scatter radar. Not only can ionospheric parameters be measured, but also interactions between the ionized and neutral gases can be determined, and some parameters of the neutral atmosphere can be inferred. It is also possible to measure the ion-neutral collision frequency and to estimate the neutral temperature through this technique.

Of particular interest to DNA are the sources and mechanisms of energy deposition in the upper atmosphere. The magnetosphere and magnetospheric/ionospheric coupling play an important role in this area. Magnetospheric electric fields redistribute and structure F-region ionization, drive the electrojet current systems, and are responsible for the joule heating of both the ionosphere and neutral atmosphere. Other magnetospheric processes are responsible for the precipitation of electrons and protons that (1) produce D-region ionization and structured E-region ionization,

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(2) deposit energy in the upper atmosphere, and (3) create the charge-carriers for the electrojet.

Structured E- and F-region ionization, electric fields, D-region ionization, and the like can affect both radar and communications systems. Systems effects derivable from incoherent-scatter experiments at Chatanika include: (1) radar refraction, scintillation, clutter, and absorption; (2) HF absorption and propagation; and (3) satellite communication link absorption and scintillation.

The value of the Chatanika facility as a research tool for both basic and applied science has been noted by a number of other U.S. Government agencies as well. Several defense related agencies, moreover, have sponsored research studies that utilize Chatanika data. For the past several years an increasing portion of the operational costs of the Chatanika facility has been supported by the National Science Foundation (NSF).

During the period 1 November 1976 to 31 October 1979, DNA has funded SRI under Contract DNA001-77-C-0042 to operate, maintain, and improve the Chatanika radar, and to carry out a program of research relevant to DNA needs. This is the Final Management Report for that contract and reviews the work performed during the contract period.

II OPERATIONS

The Chatanika radar was operated and data were collected for more than 3000 hours during the contract period. Many different types of experiments were performed; they can be broadly characterized as follows:

- Experiments in support of other DNA field programs, such as the Wideband Satellite, various IR rockets launched from Poker Flat, and the MHD/EMP Long-Lines experiments.
- Cooperative experiments with other instruments and sensors, such as NASA rocket probes, various satellites, AFGL aircraft, and ground-based optical instrumentation.
- Experiments to develop new measurement and analysis techniques.
- Experiments to apply these new techniques to the study of ionospheric, magnetospheric, and atmospheric problems of interest.
- Synoptic 24-hour experiments to determine the diurnal and seasonal variations of ionospheric parameters.
- Experiments, designed and directed by scientists from organizations other than SRI, to study various problems of interest to those experimenters.

Table 1 summarizes the hours of radar operation during the contract period. A more detailed catalogue of operations has been given in the bimonthly letter reports of the project, and is included in this report as Appendix A.

Table 1

CHATANIKA RADAR OPERATIONS SUMMARY

(November 1976 through October 1979)

Date	SRI/DNA Use	Visitor Use	Total Operating Hours
Nov 76	83	13	96
Dec 76	57	17	74
Jan 77	49	75	124
Feb 77	74	18	92
Mar 77	109	18	127
Apr 77	81	8	89
May 77	26	68	94
Jun 77	54	0	54
Jul 77			
Aug 77			0*
Sep 77			
Oct 77			
Nov 77	38	0	38
Dec 77	41	12	53
Jan 78	30	80	110
Feb 78	71	35	106
Mar 78	160	78	238
Apr 78	165	0	165
May 78	55	0	55
Jun 78	49	101	150
Jul 78	59	19	78
Aug 78	79	109	188
Sep 78	58	0	58
Oct 78	70	0	70
Nov 78	143	94	237
Dec 78	41	131	172
Jan 79	94	0	94
Feb 79	79	0	79
Mar 79	93	4	97
Apr 79	49	14	63
May 79	38	0	38
Jun 79	68	0	68
Jul 79	126	108	234
Aug 79			0†
Sep 79	22	0	22
Oct 79	49	0	49
Nov 79	38	110	148
Total	2,248	1,112	3,360

* Repair of major transmitter failure

† Installation of new Harris computer at site

III RESULTS

This section summarizes some of the significant accomplishments of the past three years. More detailed descriptions of the work are contained in Bimonthly Letter Reports 1 through 17, covering the period 1 November 1976 through 31 September 1979. A number of reports and papers have also been written and are listed in Appendix B.

- <u>Rocket Support</u>

  A significant portion of our efforts over the past three years went into supporting DNA and NASA rocket launches from the nearby Poker Flat Research Range. The Chatanika radar measurements have:

  - Provided background measurements of the condition of the ionosphere before, during, and after each launch (e.g., electron density, conductivity, electric field, neutral wind, and current density).
  - Provided estimates of energy inputs to the atmosphere from both Joule heating and particle precipitation before, during and after rocket launches.
  - Provided real-time information for use as launch criteria during the rocket countdowns.
  - Enabled cross-calibration of parameters measured by the radar with the same parameters measured by rocket.
  - Provided measurements to complement the rocket-borne sensors, either in probing different spatial regions or in measuring other fundamental parameters.

Table 2 summarizes the rocket-support missions over the three year contract period.

Table 2

CHATANIKA RADAR, ROCKET-SUPPORT OPERATIONS

Year	Number of Operations	Number of Launches
Nov 76 to Oct 77	21	9
Nov 77 to Oct 78	36	15
Nov 78 to Oct 79	27	7
Total	84	30

For rocket-support operations--in which processed Chatanika data was important to the rocket investigators--SRI prepared data reports describing the radar results. These data reports were distributed individually to the scientists involved in particular rocket experiments. The following data reports were written by SRI personnel during the past three years:

R. R. Vondrak, "Operations During Flights of Rice University Rockets 18.200 (18 February 1976) and 18.201 (1 March 1976)," [July 1977].

R. R. Vondrak and V. B. Wickwar, "Chatanika Operations During Flights of Aurorozone Rockets 18.178 (21 September 1976) and 18.179 (23 September 1976)," [August 1977].

R. R. Vondrak, "Chatanika Operations During GEOS Orbits G1 (11 June 1977), G6 (16 June 1977), and G7 (17 June 1977)," [November 1977].

R. R. Vondrak, "Operations During Flights of TMA/BA Rockets 18.1015 (28 February 1978) and 18.1016 (2 March 1978)," [May 1978].

V. B. Wickwar, "Operations in Support of Rockets of 21 and 23 September 1976," [October 1978].

R. R. Vondrak, "Operations During the Flight of Rice University Rocket 29.007 on 9 March 1978," [January 1979].

M. A. McCready and J. D. Kelly, "Chatanika Radar Operations During Flights of DNA Rockets SWIR (IC807.15-1), TMA (IC806.35-1), and IR (IR807.57-1) on 26 October 1978," [April 1979].

M. A. McCready and J. D. Kelly, "Chatanika Radar Operations During the Flight of NASA Rocket 18.101UE on 27 February, 1978," [May 1979].

M. A. McCready and R. R. Vondrak, "Chatanika Radar Operations During the Cameo Experiment on 29 October 1978," [September 1979].

In addition to the above reports produced at SRI, Chatanika radar results obtained during the launch of a SGT-HYDAC MULTI rocket, coordinated with a Wideband satellite pass, were included in a field report by AFGL, "Field Report of Coordinated Investigation of High Latitude Scintillations by Wideband Satellite, Chatanika Radar, and SGT-HYDAC MULTI Rocket Conducted 08:10:50 UT on 28 February 1978." The Chatanika results from this mission were also included in Bimonthly Letter Report 8.

- <u>Wideband Satellite Support</u>

This project has provided support for the Wideband satellite project by: (a) making measurements coordinated in time and space with passes of the satellite, (b) using Chatanika data to develop a morphological picture of auroral phenomena as related to scintillation mechanisms. Over the three year contract period, the radar has been operated for approximately 165 Wideband satellite passes. More important, the radar measurements revealed: (1) the existence of F-region ionization enhancements--limited in latitude and extensive in altitude--that are important contributors to the scintillation enhancements observed on many satellite passes, and (2) the presence of longitudinal electron-density gradients sufficiently large to support the current-convective instability now thought to be a dominant irregularity-producing mechanism in the auroral zone. These results have been communicated to the Wideband experimenters and scintillation modellers and used in their work and reports.

- Ionospheric Heating/Atmospheric Heave

The Chatanika radar has been used to study the ionospheric effects of impulsive auroral-heating events. In some cases, the time-integrated auroral-energy deposition is similar in magnitude to that expected from a high-altitude nuclear event outside the fireball region. The resulting atmospheric effects are significant. The elevated temperatures and the atmospheric heave contribute to a substantial change in F-region ion chemistry, changing the dominant F-region ion from atomic to molecular species. As a result, a significant depletion of the F-region electron density occurs. At present, these effects are not accurately predicted by the nuclear codes; because the function of the codes is to predict the large-scale perturbations. The Chatanika data can be used to improve the ambient ionospheric models and to improve the predictions of F-region changes resulting from sudden heating effects. This work has been described in detail in report DNA 5028T by J. D. Kelly, entitled "Effects of Impulsive Heating Events on F-Region Chemistry and Electron Density," SRI International (July 1979).

- MHD/EMP Experimental Program Support

The ultimate objectives of the MHD/EMP program are to (1) provide an accurate description of the large-amplitude, long-period, geomagnetic disturbances caused by a high-altitude nuclear event, and (2) obtain system-response predictions for installed power and communications systems that are subject to such a geomagnetic disturbance. The first phase of this program made use of naturally occurring auroral phenomena. The auroral electrojet provides a source that produces large geomagnetic perturbations. By monitoring ionospheric currents, magnetic perturbations on the ground, and induced voltages on power and communications lines, a model can be developed that ultimately can be applied to the nuclear situation. The Chatanika radar was used to provide the required source-term measurements (electric fields, conductivities, and currents), and the measured ionospheric currents were related to the magnetic perturbations measured on the ground. Approximately 90 hours of radar data were recorded in support of this program. Data obtained on three evenings of interest were extensively processed and analyzed. Maps of Hall and Pedersen conductivities, and northward and westward electric fields were produced, showing the variations of these parameters in time and latitude. In addition, the horizontal ionospheric currents overhead were calculated and compared with the resultant magnetic perturbations. A scaling relationship was established to relate the currents and magnetic perturbations. These results are described in detail in a recently completed data report by M. J. Baron and M. A. McCready, "Chatanika Radar Support for the DNA MHD/EMP Experimental Program," (January 1980).

- D-Region Loss Coefficients

The August 1972 solar storm produced sufficient ionization in the D-region at Chatanika to allow incoherent-scatter measurements of electron density to be made as low as 55 km altitude. The D-region ionization rates were comparable to the production rates expected from fission debris over radii of 100 to 1000 km that follow a 1-Mt nuclear burst.

Previously, extensive analyses[*†] were made of data taken simultaneously by the Chatanika radar and the DNA-supported polar orbiting satellite 1971-089. The satellite measured the particle type energy spectra from which the D-region production rate was calculated. The calculated production rate was combined with radar measurements of electron density to yield the effective D-region recombination rate.

[*] J. B. Reagan and T. M. Watt, "Simultaneous Satellite and Radar Studies of the D-Region Ionosphere During the Intense Solar Particle Event of August 1972," J. Geophys. Res., Vol. 81, p. 4579, (1976).

[†] T. M. Watt, "Effective Recombination Coefficient of the Polar D-Region Under Conditions of Intense Ionizing Radiation," DNA 3663T, SRI Project 3118, (1975).

At the time of these earlier analyses, the effect of negative ions (which are the dominant ion species at some D-region heights) on the incoherent scatter signal was not known. Recent theoretical work[‡,‡‡] has shown that the presence of negative ions can enhance the scattering cross-section of the plasma by as much as a factor of two. The August 1972 Chatanika data has been re-examined, including the appropriate negative ion correction factors. These corrections remove, to a large extent, the prominent inflection in the 60 to 80 km altitude region that was reported in the earlier work.[*,†]

A report by R. R. Vondrak and J. F. Vickrey, "Reassessment of Chatanika Radar Measurements of D-region Ionization Profiles During the August 1972 Solar Particle Events," describing the new results, is currently being prepared.

- <u>Coordinated Measurements with the Homer Radar</u>

The Chatanika radar was operated for coordinated experiments with the Homer radar and various other satellite and ground-based sensors on a number of occasions. From these experiments, a better understanding of the relationship among radar aurora, electric fields, field-aligned currents, and electron density was obtained. Six papers, the abstracts of which appear in Appendix B, describe the results of these cooperative experiments.

- <u>Electrostatic Potential Between the Ionosphere and the Magnetosphere</u>

The electrostatic potential configuration between the ionosphere and the magnetosphere is of interest in investigations of parallel electric fields and plasma-instability driving mechanisms. A method was derived to reconstruct the electrostatic potential

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‡ J. D. Mathews, "The Effect of Negative Ions on Collision-Dominated Thomson Scattering," <u>J. Geophys. Res.</u>, Vol. 83, p. 505, (1978).

‡‡ K. Fukuyama and W. Kofman, "Incoherent Scattering of an Electromagnetic Wave in the Mesosphere: A Theoretical Consideration," submitted to <u>J. Geophys. Res.</u>, (1979).

configuration, using Chatanika radar data; the method was applied to a radar observation of a quiet evening auroral arc.

The ionospheric potential, Φ_i, was obtained by integrating the relation $d\Phi_i = -E_y d_y$, where E_y is the northward component of the measured horizontal electric field, and y is the north-south distance perpendicular to the auroral arc.

At very high altitudes, somewhere between the ionosphere and magnetosphere, there is a region where auroral primary electrons are accelerated. The accelerating potential, $\Phi_{\parallel}$, was computed according to the following procedure. As a function of position across the arc, the differential electron energy distributions were calculated from the measured-density profiles. The data indicate that these energy distributions are well represented by Maxwellian distributions that have been shifted toward higher energies. This shift is the accelerating potential, $\Phi_{\parallel}$. For the auroral arc studied, the potential distribution was of the characteristic inverted "V" shape.

The magnetospheric potential, Φ_m, was then calculated from $\Phi_m = \Phi_i - \Phi_{\parallel}$--i.e., the algebraic difference between the ionospheric and parallel potentials. From these potentials, as a function of north-south distance, a graphic representation of a possible potential configuration in the accelerating region was obtained. For the case studied, the prominent features of this representation are: (1) in the accelerating region, the parallel electric field is directed upward, and the perpendicular electric field points toward the center of the inverted-V structure, and (2) the ionosphere is electrically decoupled from the magnetosphere because potential lines that originate in the ionosphere poleward of the arc center are reconnected toward the equatorward side of the inverted V. These results have been more fully described in Bimonthly Letter Report 3.

IV SYSTEMS IMPROVEMENTS

During the course of this 3-year contract, improvements to the physical facility, the radar hardware, and the computer software have been made.

The improvements to the physical facility include:

- Renovating the van air-conditioning system
- Painting of the antenna tower, the heat exchanger, and the antenna backing structure.

The following hardware was procured or constructed under this contract:

- Two new constant-current magnet power supplies
- A rebuilt switch tube (Litton L3408)
- A rebuilt klystron tube (Litton L3938)
- A spare klystron tube (Litton L3401)
- A vacion pump for the spare klystron
- The high voltage beam power supply was rebuilt after a major failure
- The "pillbox" connecting the klystron to the waveguide was replaced
- The transmitter modulator was modified to take currently available components
- The crowbar circuitry was rebuilt

Systems improvements, funded under other contracts and grants, were integrated into the radar system. The most significant of these improvements was the replacement of the antiquated XDS-930 computer with a new Harris Slash-6 computer at Chatanika.

Considerable computer software was developed under this contract. A new antenna-control algorithm was implemented on the site computer to increase antenna-mode flexibility. In addition, most of the analysis software was converted to run on the new Prime 400 computer at SRI-Menlo Park.

V CONCLUSIONS

With the termination of this project, DNA involvement in the operation and maintenance of the Chatanika Incoherent Scatter Radar Facility will end. Ownership of the facility is being transferred to the National Science Foundation. Chatanika data collected in past years, however, is continuing to be used for investigations of interest to DNA, specifically in research related to scintillation morphology and irregularity-producing mechanisms.

The United States science community is grateful to the Defense Nuclear Agency for the many years of support of the Chatanika facility. This support has made the use of the facility available to scientists from 30 organizations, resulting in the publication of over 100 journal articles.

Appendix A

CATALOGUE OF CHATANIKA RADAR OBSERVATIONS

1 November 1976 to 31 October 1979

Date*	Time Start-End	Purpose
761020	0001-0948	Synoptic 24-hour run; S3-3 satellite pass
761020	0956-1100	Wideband satellite pass
761020	1101-1924	Synoptic 24-hour run (continued)
761020	2002-2019	Atmospheric winds
761020	2028-2100	Atmospheric winds
761020 1021	2120- 0014	Synoptic 24-hour run (continued)
761021	0145-0205	Atmospheric winds
761021	0259-0450	Atmospheric winds
761021	0453-0516	Atmospheric winds
761021	0557-0617	Atmospheric winds
761021	0648-0717	Atmospheric winds
761021	0741-0833	Atmospheric winds
761021	0851-0919	Atmospheric winds
761021	1824-1842	Atmospheric winds
761021	1854-1912	Atmospheric winds
761021	2226-2244	Atmospheric winds
761021	2247-2318	Atmospheric winds
761022	1824-1844	Atmospheric winds
761022	2226-2246	Atmospheric winds
761022	2312-2330	Atmospheric winds
761022	2337-2354	Atmospheric winds
761023	0406-0525	Atmospheric winds
761023	0609-1355	AIW/AGW
761023	1652-2131	Atmospheric winds
761023	2334-2400	Atmospheric winds
761024	0013-0030	System test
761024	0036-1259	Atmospheric winds
761027	0613-1314	AIW/AGW; 8180 satellite pass
761028	0919-1124	Wideband satellite pass; 8180 satellite pass
761112	0813-1031	Wideband satellite pass
761112 1113	2227- 2244	Synoptic 24-hour run; S3-3 satellite passes (2) PF-HJNH-121 launch 1031
761114	0144-0316	Rocket support

*The date format is year-month-day (YYMMDD).

Date	Time Start-End	Purpose
761115	0205-0354	Rocket support PF-TSH-122 launch 0318
761116	0840-1119	Rocket support
761117 1118	0731- 0105	Synoptic 24-hour run; S3-3 satellite pass
761118	0818-1045	Rocket support
761119	0323-0434	Rocket support PF-TC-123 launch 0406
761119	0859-1114	Rocket support
761121	0828-1149	Rocket support
761123	0821-1037	Rocket support; Wideband satellite pass
761124	0802-1053	Rocket support
761126	0843-1119	Rocket support PF-HJNH-124 launch 1025
761127	0727-1126	Wideband satellite pass
761129	0834-1113	Rocket support
761201	0822-1043	Rocket support
761202	0830-1104	Rocket support
761209	0934-1104	Wideband satellite pass
761211	0621-1301	AIW/AGW
761212	0553-1511	AIW/AGW
761216 1217	2144-0950 1112-2216	Synoptic 24-hour run; S3-3 satellite pass
761217	0952-1107	Wideband satellite pass
761221 1222	2356- 2359	Synoptic 24-hour run; S3-3 satellite pass
- - - -	- - - -	- - - -
770105	1037-1122	Wideband satellite pass
770112	0954-1100	Wideband satellite pass
770113	0132-0340	Twilight decay
770113	0545-1133	Rocket support
770114	0125-0331	Twilight decay
770114	0617-1143	Rocket support PF-TM-125 launch 1018
770116	0133-0413	Twilight decay
770118	0540-0553	Rocket support PF-TM-126 launch 0543
770119	0002-1927 2043-2240	Synoptic 24-hour run S3-3 satellite pass 2207
770119	1929-2039	Wideband satellite pass
770126	0138-0815 0937-1025	Electric fields (plasmapause)

Date	Time Start-End	Purpose
770126	0820-0933 1026-1231	Electric fields (latitude)
770126 0127	2204- 1355	Electric fields (trough)
770127 0128	2206- 0755	Electric fields (plasmapause)
770128 0129	1903- 0348	Polar cusp
770129	0410-1251	Electric fields (altitude)
770129 0130	2209- 1313	Electric fields (trough)
770131 0201	2037- 0227	Polar cusp
770201	0244-1012	Electric fields (altitude)
770201	1023-1345	Electric fields (trough)
770203	1019-1146	Wideband satellite pass
770207	0316-0552	Rocket support PF-NT-127 launch 0451
770209	0301-0449	Rocket support
770210	0247-0446	Rocket support
770210	0944-1105	Wideband satellite pass
770211	0315-0558	Rocket support; twilight decay PF-NT-128 launch 0448
770215 0216	2206-0856 0916-1029 1118-1847 2013-2219	Synoptic 24-hour run TRIAD satellite pass 1020
770216	0859-0911	Wideband satellite pass ISIS 2 satellite pass 0900 TRIAD satellite pass 0915
770216	1031-1114	Wideband satellite pass
770216	1849-2007	Wideband satellite pass
770218	0312-0428	Twilight decay
770218	0518-0814	Auroral arc morphology
770218	0928-1213	Wideband satellite passes (2)
770222	0919-1035	Ionospheric/magnetospheric coupling TRIAD satellite pass 0924 S3-3 satellite pass 0931 Wideband satellite pass 0937
770223	0716-1335	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0736,0929 TRIAD satellite pass 0853 S3-3 satellite passes 0913,1209 Wideband satellite passes 1016, 1200

Date	Time Start-End	Purpose
770224	0830-1558	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0814,1007 Wideband satellite passes 0911, 1136 TRIAD satellite pass 1003 S3-3 satellite pass 1152 S3-2 satellite pass 1516
770226	0722-1131	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0735,0929 TRIAD satellite pass 0901 S3-3 satellite pass 1116
770227	0741-1133	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0813,1006 TRIAD satellite passes 0831,1011 S3-3 satellite pass 1058 Wideband satellite pass 1111
770228	0913-1200	Ionospheric/magnetospheric coupling TRIAD satellite pass 0940 S3-3 satellite pass 1040
770301	0659-1134	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0735,0928 Wideband satellite passes 0901, 1046 TRIAD satellite pass 0910 S3-3 satellite pass 1022
770302	0722-1244	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0813,1005 TRIAD satellite pass 0839 Wideband satellite pass 0941 S3-3 satellite pass 1004
770303	0632-1112	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0657,0850 TRIAD satellite passes 0808,0949 S3-3 satellite pass 0946
770304	0702-1122	Ionospheric/magnetospheric coupling ISIS 2 satellite passes 0735,0927 Wideband satellite pass 0916 TRIAD satellite pass 0918 S3-3 satellite pass 0928
770305	0709-1022	Ionospheric/magnetospheric coupling ISIS 2 satellite pass 0812 TRIAD satellite pass 0847 S3-3 satellite pass 0910
770310	0409-1010	Twilight decay
770311	0958-1033	Wideband satellite pass

Date	Time Start-End	Purpose
770315 0316	2139-0954 1035-1142 1218-2013 2055-2159	Synoptic 24-hour run
770316	1005-1028	Wideband satellite pass
770316	1147-1213	Wideband satellite pass
770316	2024-2047	Wideband satellite pass
770319	0433-0601	Twilight decay
770319	0610-1349	AGW
770322	0828-1134	Auroral arc morphology TRIAD satellite pass 0827 S3-3 satellite pass 0850 8180 satellite pass 0938
770323	0715-1426	Auroral arc morphology 8180 satellite passes 0853, 1032,1212 Wideband satellite pâsses 0941, 1125
770323	2117-2400	Wideband satellite pass
770324	0638-1306	Auroral arc morphology TRIAD satellite passes 0726,0906 S3-3 satellite pass 0827 8180 satellite passes 0947,1127 Wideband satellite passes 1020, 1204
770325	0648-1141	Auroral arc morphology S3-3 satellite pass 0806 TRIAD satellite pass 0859 8180 satellite passes 0902,1044 Wideband satellite passes 0915, 1100
770326	0630-1318	Auroral arc morphology S3-3 satellite pass 0744 TRIAD satellite pass 0805 8180 satellite passes 0818,0957
770327	0732-1018	Auroral arc morphology 8180 satellite pass 0912
770328	0726-1353	Auroral arc morphology 8180 satellite passes 0827,1007
770329	0614-1358	AGW 8180 satellite passes 0922,1101 S3-3 satellite pass 0938
770330	0700-1312	Auroral arc morphology TRIAD satellite pass 0745 8180 satellite passes 0837,1016 Wideband satellite passes 0905, 1050,1233
770331	0706-1242	Auroral arc morphology TRIAD satellite pass 0711 8180 satellite passes 0752, 0931,1111 S3-3 satellite pass 0854

Date	Time Start-End	Purpose
770401	0837-1231	Wideband satellite passes S3-3 satellite pass 0935
770405	0619-1016	AE-C satellite passes
770405 0406	2049- 2155	Synoptic 24-hour run
770407	0523-1056	Auroral arc morphology
770408	0325-1202	Auroral arc morphology
770409	0559-1201	Transport (neutral winds)
770418	1935-2244	Polar cusp
770419 0420	2148- 2200	Synoptic 24-hour run Wideband satellite pass 1045
770428	1015-1137	Wideband satellite pass
770508	2144-2322	D-layer (absorption)
770509 0510	1813- 1838	Polar cusp
770513	0944-1108	Wideband satellite pass
770515	1200-1405	D-layer (absorption)
770515	1430-2138	Polar cusp
770516	0012-1814	Polar cusp
770517	1648-1735	D-layer (absorption)
770517	1754-2104	Polar cusp (ionosonde comparison)
770518 0519	0112-0951 1051-1144 1204-2025 2045-0114	Synoptic 24-hour run
770518	0954-1040	Wideband satellite pass
770518	1149-1200	Wideband satellite pass
770518	2029-2040	Wideband satellite pass
770526	0532-0629	Transport
770611	0340-0716	GEOS satellite pass
770616	0145-2400	Synoptic 24-hour run
770617	0413-0641	GEOS satellite pass
771110	0941-1116	Rocket support
771117	0824-1121	Rocket support
771118	0753-1207	Rocket support Wideband satellite pass 1015
771119	0914-1053	Rocket support Wideband satellite pass

Date	Time Start-End	Purpose
771123	0000-9758 0829-0956 1014-1130 1204-2327	Synoptic 24-hour run
771123	0801-0825	S3-3 satellite pass 0803 Wideband satellite pass 0819
771123	1001-1011	Wideband satellite pass 1006
771123	1135-1155	Wideband satellite pass 1145
771129	1000-1136	ISIS-2 satellite pass 1036
771130	0954-1143	S3-2 satellite pass 1100
771202	0931-1100	ISIS-2 satellite pass 1038
771204	2120-2349	ISIS-2 satellite pass
771205 1206	1913- 0259	Polar cusp
771207	0021-0949	Synoptic 24-hour run
771219 1220	2039- 2152	Synoptic 24-hour run
771222	1137-1244	AE C satellite pass 1209
771224	0742-0957	AE-C satellite pass 0834
771228	0943-1056	Wideband satellite pass 1031
771229	0819-0930	ISIS-2 satellite pass 0900
771229	0932-1032	AE-C satellite pass 0949
771230	1004-1039	Wideband satellite pass 1012
780104	0805-0918	AE-C satellite pass 0835
780105	0735-1402	AGW
780109	0647-0931	AE-C satellite pass
780109 0110	2117- 1152	Polar cleft; polar oval
780111	2019-2335	Polar cleft
780111 0112	2351- 1130	Trough
780113	0027-0113	Plasmapause
780113	0703-1221	Plasmapause; polar oval
780113 0114	2328- 0642 0751-1151	Trough
780114	0650-0743	ISIS-2 satellite pass 0715
780116	0106-0223	Polar oval
780116	1854-2007	ISIS-2 satellite pass
780118	0004-1010 1110-2355	Synoptic 24-hour run
780118	1015-1056	Wideband satellite pass 1035
780119	1027-1150	Wideband satellite pass 1115

Date	Time Start-End	Purpose
780125	0923-1212	Wideband satellite passes 1000, 1145 S3-2 satellite pass 1010 TRIAD satellite pass 1140
780128	1124-1233	Wideband satellite pass 1159 TRIAD satellite pass 1149
780129	0340-0724	Rocket support
780130	0331-0905	Rocket support
780131	0336-1100	Rocket support S3-2 satellite pass 0958 Wideband satellite pass 1029
780201	0330-1148	Rocket support S3-2 satellite pass 1109 TRIAD satellite pass 1126
780202	0338-1216	Rocket support PF-TM-133 launch 0854 Wideband satellite passes 1004, 1148 S3-2 satellite pass 1047 TRIAD satellite pass 1056
780203	0825-1257	Wideband satellite passes 0859, 1044, 1227 S3-2 satellite pass 1023 TRIAD satellite pass 1025
780204	0739-1153	Wideband satellite passes 0939, 1123 TRIAD satellite pass 1135
780205	1812-2107	Wideband satellite passes 1854, 2039 ISIS-2 satellite pass 1900 S3-2 satellite pass 2023
780206	0840-1259	Wideband satellite passes 0914, 1058, 1242 TRIAD satellite passes 1034, 1214 S3-2 satellite pass 1045
780206	1722-2148	Wideband satellite passes 1750, 1939, 2119 ISIS-2 satellite passes 1744, 1938
780207	0839-1154	Wideband satellite passes 0954, 1138 TRIAD satellite passes 1003, 1143 S3-2 satellite pass 1019
780207	1736-2046	Wideband satellite passes 1830, 2014 ISIS-2 satellite pass 1822
780208	0009-1026 1041-1210 1234-2234	Synoptic 24-hour run S3-2 satellite pass 0954 TRIAD satellite pass 1113
780208	1028-1039	Wideband satellite pass 1034
780208	1211-1223	Wideband satellite pass 1218

Date	Time Start-End	Purpose
780209	0850-1142	Wideband satellite passes 0929, 1113 S3-2 satellite pass 0928 TRIAD satellite pass 1042
780210	0919-1221	Wideband satellite passes 1008, 1152 TRIAD satellite pass 1011 S3-2 satellite pass 1036
780211	0613-1358	AGW
780227	0428-0645	Rocket support PF-NT-134 launch 0543 Barium release 0549
780227	1223-1510	Plasma line test
780228	0237-0520	Rocket support PF-NT-135 launch 0417
780228	0523-1224	Rocket support Wideband satellite passes 0806, 0946 PF-SH-136 launch 0810 TRIAD satellite pass 0930 PF-TSH-137 launch 1144
780228	1351-1535	Plasma line
780301	0510-1236	Rocket support; pulsating aurora Wideband satellite passes 0846, 1031, 1216 TRIAD satellite pass 0859 S3-2 satellite pass 1022
780301	1747-2108	Rocket support PF-HJH-138 launch 1906 Wideband satellite passes 1907, 2051
780302	0241-1312	Rocket support PF-NT-139 launch 0423 TRIAD satellite passes 0827, 1010 Wideband satellite passes 0926, 1111, 1248
780303	0530-1402	Rocket support; pulsating aurora Wideband satellite passes 0821, 1006, 1151, 1334 TRIAD satellite pass 0939 AE-C satellite pass 1310
780304	0536-1311	Rocket support Wideband satellite passes 0908, 1012 TRIAD satellite pass 0908 S3-2 satellite pass 1012
780305	0606-1318	Rocket support; Homer radar comparison TRIAD satellite passes 0837, 1017 Wideband satellite passes 0941, 1126, 1309 AE-C satellite pass 1251

Date	Time Start-End	Purpose
780306	0627-1245	Rocket support TRIAD satellite passes 0805, 0947 Wideband satellite pass 0836 AE-C satellite pass 1150
780308 0309	0000-0823 0902-0947 1003-1128 1144-0017	Synoptic 24-hour run
780308	0836-0859	TRIAD satellite pass 0846
780308	0949-1001	Wideband satellite pass 0956
780308	1129-1141	Wideband satellite pass 1140
780309	0558-1335	Rocket support PF-TM-140 launch 0813 TRIAD satellite pass 0818 S3-2 satellite pass 1020 Wideband satellite passes 1036, 1220 AE-C satellite pass 1132
780310	0550-1350	Rocket support TRIAD satellite pass 0926 Wideband satellite pass 0931 PF-NT-141 launch 1315 Barium release 1321
780311	0632-1204	Rocket support TRIAD satellite pass 0855 AE-C satellite pass 1059
780312	0646-1133	Rocket support
780313	0636-1345	Rocket support AE-C satellite pass 1029
780313	1438-1600	Plasma line
780314	0742-1310	Rocket support
780314	1346-1530	Plasma line
780316	0724-1622	Plasma line
780317	0824-1557	Plasma line
780318	0955-1505	Plasma line
780319	0913-1527	Plasma line
780319	2303-2330	Plasma line
780320	0230-0304	Atmospheric winds (test)
780320	0447-1430	Plasma line
780321	2039-2151	Atmospheric winds (test)

Date	Time Start-End	Purpose
780322	0551-0809	Rocket support
780323	0536-0756	Rocket support
780323	0817-0859	Atmospheric winds (test)
780326	0552-1258	Rocket support
780327	0809-1453	Rocket support PF-NT-142 launch 1027
780328	0437-0543	Atmospheric winds (test)
780328	0802-1354	Rocket support
780329	0713-0750	Atmospheric winds (test)
780329	0800-1807	Rocket support PF-NT-143 launch 1650
780330	0154-0328 0608-0637	Atmospheric winds (test)
780330 0331	2334- 0600	Atmospheric winds (test) Balloon launch 0330
780331	0616-0709	Rocket support
780331	0733-0931	Atmospheric winds (test)
780331	0937-1024	AE-C satellite pass
780331 0401	2134-	Atmospheric winds (test)
780401 0402	1957- 0342	Atmospheric winds
780402	0524-0848	Atmospheric winds
780402 0403	2248- 0920	Atmospheric winds
780403 0404	2322- 0828	Atmospheric winds
780404	2248-2344	Atmospheric winds
780405	0136-2246	Atmospheric winds
780406 0407	0255- 0333	Atmospheric winds
780407 0408	2223- 0027	Atmospheric winds
780408	2102-2210	Atmospheric winds
780409	0344-1600	Electric fields (comparison with balloon and Millstone Hill) Balloon launch 0330
780411	0603-1201	High latitude ionosphere/aurora
780412	0015-2400	Synoptic 24-hour run

Date	Time Start-End	Purpose
780413 0414	0001- 0633	Solar flare
780414	0643-1830 1920-2019 2030-2139	Solar flare
780414	1832-1919	Wideband satellite pass
780414	2020-2028	Wideband satellite pass
780423	0722-1214	Homer radar comparison Wideband satellite pass 0902 Wideband satellite pass 1047
780425	0700-1151	Homer radar comparison Wideband satellite pass 1022
780501	0735-0937	Wideband satellite pass
780501	1639-2129	Wideband satellite passes
780502	0845-1332	Wideband satellite passes
780502	1745-1755	Wideband satellite pass
780510	0001-0943 0958-1127 1141-1312 1327-1817 1835-2010	Synoptic 24-hour run
780510	0945-0956	Wideband satellite pass
780510	1128-1140	Wideband satellite pass
780510	1313-1325	Wideband satellite pass
780510	1820-1832	Wideband satellite pass
780516	0937-1233	Wideband satellite passes
780516	1834-1901	Wideband satellite pass
780522	0831-1249	Wideband satellite passes
780522	1720-2126	Wideband satellite passes
780523	0853-0959	Wideband satellite pass
780523	1741-2225	Wideband satellite passes
780524	1000-1234	Wideband satellite passes
780524	1831-2101	Wideband satellite passes
780607	0001-2400	Synoptic 24-hour run
780614 0615	2102- 2119	Synoptic 24-hour run
780619 0620	1936- 0100	Polar cleft
780620	0102-1013	Plasmapause

Date	Time Start-End	
780621 to 0623	1952- 0749	Electric fields (latitude; coop with Millstone Hill) ISIS-2 satellite passes 2128, 0234,0826,1022,1235 ISIS-1 satellite passes 0644,0901 AE-C satellite passes 0738,0908, 0600,0730
780624 0625	1702- 0316	Polar cleft
780627 to 0629	1657- 1252	Electric fields (latitude; coop with Millstone Hill) ISIS-2 satellite passes 2118,0042, 0234,0432,0630,1019,1236,1620, 1807,2001,2331,0021,0120,0516, 0709,1117 ISIS-1 satellite passes 2200,0007, 0153,0353,0818,1238,1922,2341, 0328,0532,0747,0959,1209 ISE-E satellite passes 0000 to 0630 AE-C satellite passes 0501,0630, 0801,0451,0619,0749
780707	0403-1601	Synoptic 12-hour run
780712	0007-0055 0345-0528	Synoptic 24-hour run (aborted)
780712 0713	2009- 2008	Synoptic 24-hour run
780720	0602-1601	Gravity wave
780724 0725	1625- 0203	Polar cusp (ionosonde comparison)
780728	0403-1603	Synoptic 12-hour run
780801 0802	2304- 2313	Synoptic 24-hour run
780803 0804	1559- 0122	Polar cusp (ionosonde comparison)
780804 0805	1821- 0207	Polar cusp (ionosonde comparison)
780810	0014-0400	Electric fields (comparison with balloon)
780810	0404-1622	Synoptic 12-hour run
780810 to 0814	{1626- 0012}	Electric fields (comparison with balloon)
780818	1354-1453	AE-C satellite pass
780823 0824	0125-1401 1439-0113	Meridional neutral winds
780823	1403-1437	AE-C satellite pass

Date	Time Start-End	Purpose
780824	0356-1604	Synoptic 12-hour run AE-C satellite pass at 1305
780829	0527-1015	Solar flare
780906 to 0907	0001-1003 1016-1423 1457-1840 1851- 0004	Synoptic 24-hour run
780906	1003-1015	Wideband satellite pass
780906	1423-1457	AE-C satellite pass
780906	1840-1851	Wideband satellite pass
780908	0905-1007	AE-C satellite pass
780912	1040-1258	AE-C and Wideband satellite passes
780915	1103-1208	AE-C and Wideband satellite passes
780921 0922	0059- 0119	CHAMP (CHatanika Auroral Morphology Program) Wideband satellite passes 1808, 1950, 2138
780925 0926	2235- 0213	Synoptic 4-hour run
781012	0843-1345	Wideband satellite pass
781017 1018 1019	2350- 0012	Synoptic 24-hour run
781025 1026	0208- 0203	CHAMP (CHatanika Auroral Morphology Program)
781026	0532-1047	Rocket support PF-NH-145 launch 0916 PF-NJ-146 launch 0920 PF-NH-147 launch 0929
781027	0635-0747	Rocket support
781028	0504-0711	Rocket support
781029	0428-0629	Rocket support PF-TC-148 launch 0502
781029	1025-1145	CAMEO satellite barium release
781102	0601-0858	Rocket support
781102	0913-0934	Wideband satellite pass
781102	0947-1037	Rocket support
781102	1045-1147	Wideband satellite pass
781103	0539-0943	Rocket support

Date	Time Start-End	Purpose
781103	0946-1104	AE-C and Wideband satellite passes
781103	1105-1216	Rocket support
781104	0547-1114	Rocket support
781105	0533-1036	Rocket support
781106	0525-1158	Rocket support
781107	0532-1148	Rocket support
781108	0600-1316	Rocket support
781109	0635-1246	Rocket support
781110	0726-1318	Rocket support
781111	0708-1231	Rocket support
781112	0727-1427	Rocket support
781113	0833-1336	Rocket support PF-SGT-149 launch 1244
781113 1114	2251- 0230	Plasma line
781114	0355-1640	Plasma line
781114	2303-2338	D-region (test)
781115 1116	0010- 0027	Synoptic 24-hour run
781116 1117	0618- 0614	CHAMP (CHatanika Auroral Morphology Program)
781117	0922-1318	Plasma line
781117	1357-1459	AE-C satellite pass
781118	1332-1448	AE-C satellite pass
781119	0002-0445	Plasma line
781119	1204-1600	Plasma line
781119 1120	2242- 0303	Plasma line
781120	0924-1330	Plasma line
781120	2157-2311	Plasma line
781120 1121	2319- 0013	F-Region study
781121	0315-0422	Plasma line

Date	Time Start-End	Purpose
781121	0916-1150	Plasma line
781121	1205-1254	AE-C satellite pass
781121	1312-1452	Plasma line
781121 1122	2200- 0022	D-region test
781122	0054-0320	Plasma line
781122	0700-1645	Plasma line
781122 1123	2334- 0127	Plasma line
781123	0142-0256	F-region study
781123	1042-1438	Plasma line
781123	2219-2315	Plasma line
781125	0155-0318	Plasma line
781125	0531-1549	Plasma line
781125 1126	2302- 0031	Plasma line
781126	0913-1426	Plasma line
781126 1127	2300- 0030	Plasma line
781129	0705-1326	AE-C and Wideband satellite passes
781130	0849-1344	MHD/EMP-long lines
781201	0906-1311	MHD/EMP-long lines
781202	0852-1217	MHD/EMP-long lines
781203	0956-1119	MHD/EMP-long lines
781204	0930-1435	MHD/EMP-long lines
781205	0932-1228	MHD/EMP-long lines
781206	0938-1129	MHD/EMP-long lines
781207	0603-1008	AE-C and Wideband satellite passes
781207	1013-1348	MHD/EMP-long lines
781208	0740-1345	MHD/EMP-long lines
781209	0720-1206	MHD/EMP-long lines
781210	0643-0857	AE-C satellite pass
781211 1212	2221- 0510	Trough formation

Date	Time Start-End	Purpose
781213 1214	0006- 0019	Synoptic 24-hour run
781214 1215	0138- 1110	Electric fields (coop with St. Santin)
781216 1217 1218	1609- 0416	Electric fields and polar cleft
781218 1219	2332- 0707	Trough formation
781220	0257-1138	Electric fields
781221	0308-0728	Particle precipitation
781221	0733-0944	Electric fields
790103 0104 0105	2343- 0002	CHAMP (CHatanika Auroral Morphology Program)
790117	0553-1103	Synoptic 24-hour run (aborted)
790120	0452-0914	Rocket support
790121	0538-0933	Rocket support
790122	0518-1122	Rocket support
790123	0540-1242	Rocket support
790124	0506-1145	Rocket support
790124	1148-1159	Pulsating aurora experiment
790125	0456-1221	Rocket support
790126	0456-1224	Rocket support PF-TM-150 launch 1101
790127	0958-1058	Wideband satellite pass
790129	0531-1217	Wideband satellite passes and aircraft
790129	1222-1257	MHD/EMP-long lines
790129	1259-1329	Pulsating aurora experiment
790129	1331-1405	MHD/EMP-long lines
790130	0853-1012	MHD/EMP-long lines
790130	1020-1109	Wideband satellite pass
790130	1112-1157	MHD/EMP-long lines
790131	0859-1400	MHD/EMP-long lines
790201	0823-1006	MHD/EMP-long lines
790201	1014-1036	Wideband and S3-3 satellite passes
790201	1040-1114	MHD/EMP-long lines

Date	Time Start-End	Purpose
790203	0950-1108	Wideband Satellite Pass
790203	1115-1145	Pulsating Aurora
790204	0942-1036	Wideband Satellite Pass
790205	0913-1324	Wideband Satellite Passes
790206	0651-1317	L-Shell Experiment
790207	0833-1310	Wideband Satellite Passes
790213	1029-1139	Wideband Satellite Pass
790213 0215	2358-0007	Synoptic 24-Hour Run
790220 0222	2350-0000	CHAMP (CHatanika Auroral Morphology Program)
790226	1400-2000	Solar Eclipse Experiment
790314 0316	2352-0009	CHAMP (CHatanika Auroral Morphology Program)
790321 0322	0004-0002	Synoptic 24-Hour Run
790323	0900-1247	MHD/EMP Long Lines
790324	0736-0916	L-Shell Experiment
790324	0923-1336	MHD/EMP Long Lines PF-HJ-151 Launch 1104
790325	0431-0530	D-Region Profiles
790325	0813-1339	MHD/EMP Long Lines
790326 0327	2233-0035	D-Region Profiles
790327	0822-1356	MHD/EMP Long Lines
790328	0819-1351	MHD/EMP Long Lines
790329	0720-1249	MHD/EMP Long Lines
790330	0714-1152	MHD/EMP Long Lines
790402 0403	0003-0001	CHAMP (CHatanika Auroral Morphology Program)
790404	0027-0237	D-Region Profiles
790415	0608-1049	Rocket Support PF-NT-153 Launch 0925 PF-TM-154 Launch 0931
790416	0643-0918	Rocket Support
790417	0636-1000	Rocket Support
790418 0419	0008-0009	Synoptic 24-Hour Run PF-TM-155 Launch 0909 PF-NT-156 Launch 0915

Date	Time Start-End	Purpose
790515 0517	2345- 0005	CHAMP (CHatanika Auroral Morphology Program)
790523 0524	2356- 1343	Synoptic 24-Hour Run
790605	0755-0958	L-Shell Gradients
790606	2050-2310	D-Region Profiles
790607	0758-1000	L-Shell Density Gradients
790607	1006- 2100	Meridional Neutral Winds
790612 0614	2354- 0011	CHAMP (CHatanika Auroral Morphology Program)
790619 0620	2354- 2359	Synoptic 24-Hour Run
790706	0002- 1151	CHAMP (CHatanika Auroral Morphology Program)
790712 0714	0543- 0914	Ionospheric Convection
790717 0719	0606- 0754	Ionospheric Convection
790719 0720	1817- 0135	Polar Cusp
790720 0721	1703- 0120	Polar Cusp
790722	0404-0808	Atmospheric Winds
790722	1720-2246	Atmospheric Winds
790722 0723	2252- 0141	Atmospheric Winds
790723 0724	1818- 0502	Atmospheric Winds
790724 0725	1854- 0442	Atmospheric Winds
790725	0531- 1730	Atmospheric Winds
790726 0727	1841- 0405	Atmospheric Winds
790727	0507- 1906	Atmospheric Winds
790727 0728	2156- 0636	Atmospheric Winds
790728	1435- 2321	Atmospheric Winds
790729	1500- 1932	Atmospheric Winds
790729 0730	2143- 0637	Atmospheric Winds

Date	Time Start-End	Purpose
790920 0921	2025- 0728	Solar Flare
790926	2118-2259	Equipment Test
791005	0624-0835	Triad Satellite Pass
791009	0605-0801	Triad Satellite Pass
791012	0621-0734	Triad Satellite Pass
791012	0735-0936	L-Shell Gradients
791017 1018	0037- 0021	Synoptic 24-Hour E-Fields Experiment
791018	0730-0931	EXCEDE Rocket Support
791019	0514-0612	EXCEDE Rocket Support
791020	0522-0718	Triad Satellite Pass
791027	0536-0803	Triad Satellite Pass
791030	0414-0802	Triad Satellite Passes
791031	0448-0719	Triad Satellite Pass

Appendix B

PAPERS RELATED TO THE CHATANIKA RADAR CONTAINING CONTRIBUTIONS BY SRI PERSONNEL WHOSE WORK WAS WHOLLY OR PARTLY SUPPORTED BY CONTRACT DNA001-77-C-0042

SRI International Project 5915

APPENDIX B

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